VALTION MAATALOUSKOETOIMINNAN JULKAISUJA N:o 151
PUBLICATIONS OF THE FINNISH STATE AGRICULTURAL RESEARCH BOARD No. 151

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SELOSTUS: *JYRÄYKSEN VAIKUTUKSESTA OHRAN JA KAURAN SATOON SEKÄ SUOVILJELYKSEN LÄMPÖOLOIHIN*

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Contents

Introduction

The compaction of the soil caused by rolling changes the properties of the cultivated layer in many different respects. Its immediate effect is to create a substrate of a different kind for cultivated plants; the moisture conditions in the soil are changed, and furthermore, the changes in the physical condition of the soil affect its specific heat and thermal conductivity.

In the summer of 1955 an experiment concerning the rolling of cultivated peat land was arranged at Pelsonsuo Frost Research Station using two test plants, barley and oats. The object was to study the direct influence of rolling upon the crop yield under these conditions. The test fields of the Station having been reclaimed for cultivation in 1952 and, consequently, still having a loose cultivated layer it was to be expected that the effect of rolling would be discernible insofar as the method is of any practical significance. In connection with this test attention was further given to the thermal conditions in the soil and in the air next to the ground. These investigations are primarily of interest because it is obvious that, particularly in boreal cultivated areas, the thermal conditions of the soil may be of considerable importance from the standpoint of the growth of cultivated plants and also of indirect influence, affecting for instance the amount of frost damage suffered by the plants. Moreover, the physical characteristics of the soil affect the static cooling of the air, and it was therefore of interest to find out how far it is possible by rolling to affect, for instance, the occurrence of night frost.

I. Plant cultivation experiments

1. *The establishing of the test areas, their treatment, and the weather conditions*

The test was arranged on cultivated peat land which carried its third cereal crop since the reclaiming of the land. The peat was still rather poorly humified sedge peat. No mineral soil had been used on the test area to improve its soil quality. The width of the strips, from centre of ditch to centre of ditch was 20 m. The cultivated layer had a depth of about 23 cm. The test area had been ploughed in the autumn and it was harrowed with a tractor-drawn harrow on 22. V. The fertilizers (300 kg rock phosphate, 200 kg 50 per cent potash salt, 65 kg nitro-chalk, 20 kg Cu roasted, per hectare) were spread by hand; the sowing was performed before rolling. The test plots were rolled on 3. VI and the thermocouples were put in place on 4. VI.

The test comprised: plots which were not rolled and plots rolled with a cambridge roller and with a smooth surface concrete roller, respectively. Both rollers were of approximately the same weight and they were drawn by manpower. The test areas were located in such a way that the rolled and untreated plots were across the strip between two ditches. Seven replicates were used. Two experimental plants were used in the test, one half of each plot, in its longitudinal direction, being sown with oats and the other half with barley. The plot size of the barley and oats tests was 31.3 and 44.3 m^2, respectively. Barley was sown in an amount of 120 kg of germinating seeds per hectare, oats: 140 kg per hectare.

At threshing, samples were taken from the grain crop and their moisture content was determined. The grain yield was calculated for a moisture content of 15 %. The straw yield has been measured in the air-dried state.

The weather conditions can be seen from table 1. It is seen that the summer was fairly normal with regard to its temperature conditions except for August and September, which were warmer than normal. Since the rainfall was low in June and August, there is also reason to study the distribution of the rains. In June the rainfall was fairly evenly distributed,

Table 1. Pentad mean temperatures and rainfall, May to September 1955.

Days	Temperature, °C					Rainfall, mm				
	V	VI	VII	VIII	IX	V	VI	VII	VIII	IX
1— 5......	0.6	13.8	15.0	13.0	13.1	0	0	3	5	30
6—10......	1.9	4.8	17.1	15.3	10.9	0	4	18	6	5
11—15......	3.4	11.3	19.5	16.4	10.9	0	2	0	0	19
16—20......	7.2	9.6	12.6	18.9	12.6	0	15	49	0	13
21—25......	5.5	13.5	12.1	15.4	5.9	12	10	0	0	21
25—30 (31)..	7.6	13.3	17.4	16.4	8.5	14	0	0	1	1
Month	4.5	11.0	15.7	15.4	10.3	26	31	70	12	81
Normal	5.9	11.8	15.2	12.3	7.2	42	61	71	77	62

but the last three weeks in August were nearly rainless. Moreover, a rainless spell of about 10 days occurred in the second half of July.

2. *Results of the experiment*

Table 2 shows the results of the plant growth studies in the rolling experiment. It is seen that both the grain crop and the straw yield were lowest on the untreated test plots. On the other plots the grain and straw yields were higher in comparison with the untreated plot in approximately the same proportion. The increase in grain yield produced by rolling was somewhat higher with barley than with oats.

Table 2. Experimental results of the cultivation test. Date of sowing: June 2nd. Date of cutting: oats, September 23rd; barley, September 7th.

Orion III-oats	Grain yield		Straw yield		Straw grain yield ratio	1 000-g. w., g	Straw length, cm
	kg/ha	Ratio	kg/ha	Ratio			
Not rolled..........	970	100	3 340	100	3.4	33.2	83
Rolled, cambr. roller	1 250	129	4 540	136	3.6	35.6	88
» , concr. roller	1 300	132	4 600	138	3.5	33.3	87
Tammi-barley							
Not rolled..........	250	100	1 320	100	5.3	27.6	—
Rolled, cambr. roller	650	260	2 330	176	3.6	29.8	—
» , concr. roller	710	284	2 300	174	3.2	27.6	—

	F-value	Significant difference, kg/ha	m-%
Oats, Grain yield	2.82°	434	12.2
Straw yield	5.76*	1 390	10.8
Barley, Grain yield	4.28*	574	3.4
Straw yield	12.38*	746	1.2

The results of the error calculation (table 2) reveal that the deviations between the replicates of one and the same test member were considerable, as was observable by eye during the entire growing season.

The observations made during the growing period show differences between the different test plots primarily only in that the length of the straws remained shortest on the untreated plot throughout the growing season. Before the cutting of the test areas, samples of the oats were taken for determination of the straw length. Table 2 shows that the straw length was 4—5 cm less on the untreated test plot than on the rolled plots.

In a study of the results of these experiments, attention is drawn to the consistently low grain yield in comparison with the straw yield, which has been fairly abundant in all cases. Although night frosts of —3.0 and —4.0 °C occurred in the latter half of August, no effect of these frosts was visible to the eye, perhaps owing to the seasoning of the grain by the low rainfall of the summer; on the contrary, the cereal on the test plots ripened quite well. The main reason for the low grain crops is the occurrence of deficiency in copper, in spite of the addition of copper fertilizer. Moreover, this deficiency appeared very irregularly, to which fact again the great variations between the replicates can be ascribed. The likelihood of deficiency in copper was already known at the time of establishing this test from previous experience, copper deficiency having been noticed every year on this bog if no mineral soil was used to improve the soil. As has already been mentioned, this rolling test was established on a strip of land which had not been given any addition of mineral soil.

The deficiency in copper was primarily evident in the grain crops. The number of grains was fairly normal in the case of oats by ocular assessment, but the formation of light grain was very frequent. The misproportion between the straw yield and the grain yield is seen from the ratios given in table 2. In a normally developed crop, even on a bog, this ratio should not exceed 2, but in this test the said figure is greater than 3 for all test members. In the case of barley it is found that rolling reduces the ratio between straw yield and grain yield.

It was thus possible even in advance to anticipate an influence of copper deficiency upon the results, and this was merely a disturbing influence, since the object was not to study the effect of rolling upon the occurrence of copper deficiency. Nevertheless the test was established on a soil of pure peat and not on a strip admixed with mineral soil. This for the reason that, in accordance with the primary investigative work of the research station, the studies of the thermal conditions in connection with this test were considered the most important object of the investigation. If the test had been established on a strip where mineral soil had been used for its improvement, the performing of the temperature measurements would

have been rendered more difficult. The non-uniform presence of mineral soil in the cultivated layer would have considerably increased the inhomogeneity of the soil, thus making it more difficult to obtain a clear idea of the thermal conditions in the soil. It cannot be assumed that the spreading of mineral soil in connection with the reclamation of a peat bog would have been performed with adequate uniformity from this standpoint. On the other hand, even a preliminary theoretical consideration revealed that only fairly small temperature differences between the different test plots were to be expected.

II. Investigations relating to the thermal conditions

The radiant energy arriving from the sun and the sky constitutes the main source of heat energy of the earth's surface layers. Energy is lost from the earth's surface as reflected radiation and by means of emitted radiation. The difference between the energy received and that given off by the earth is called its radiation balance (net radiation). Part of the quantity of energy which is numerically given by the radiation balance is used to warm up the uppermost soil layers, another part being consumed in warming up the adjacent air and part being dissipated by evaporation. It is thus evident that the thermal conditions in the soil are affected by the height of the radiation balance and by the way in which the surface layers of the soil use this energy.

The earth's reflecting power is called its albedo. In the case of a surface bare of vegetation the albedo depends on the type of soil, the moisture content of the soil and the colour of the soil, among other things. According to Ångström (1925) the albedo decreases with increasing moisture content of the soil surface. Likewise the outgoing radiation from the earth, which takes place at all times of the day and night, is of influence upon the radiation balance. This outgoing radiation depends on the temperature of the soil surface, increasing with increasing temperature.

In the daytime a considerable part of the radiant energy, the amount of which is given by the radiation balance, is used to warm up the top layers of the soil. Thus, in the daytime heat travels downward in the soil. At negative radiation balance, in the night-time, heat transfer in the opposite direction takes place. How rapidly heat is conducted from one soil layer to another depends, for instance, on the thermal conductivity of the soil, the rate of heat transfer increasing with increasing thermal conductivity. Since air is of extremely low thermal conductivity in comparison with soil and with water, loose soil is inferior in thermal conductivity to compact soil, and dry soil to wet soil.

The thermal energy consumed by evaporation is dependent on the temperature, the moisture content of the soil and the humidity of the air, and on its exchange. Obviously more water evaporates from a wet

than from a dry soil surface. Evaporation mainly takes place in the daytime, since the quantities of heat required are frequently lacking in the night. In the night, actually, the opposite phenomenon is often observed, i. e., the precipitation of water vapour in the form of dew or hoarfrost.

It is evident from all this that the physical state of the soil is of consequence with regard to the thermal economy of the soil. Changes in the thermal conditions of the soil can thus be expected as a result of rolling, since this operation produces physical changes in the soil. Since, furthermore, it is known that the quality of the soil also affects the adjacent air layer, changes caused by rolling are to be expected in the thermal conditions of the air layer next to the ground.

1. *Measurements of temperature*

The soil temperature measurements were carried out with the aid of thermocouples (Pessi 1956). The depths of measurement were 10 and 20 cm. Three replicates were used. Temperature measurements were also performed on the soil surface, but these measurements were abandoned since their deviations were too high to reveal any reliable differences. This was caused among other things, by the inhomogeneity of the soil surface, which was due to undecayed plant remnants. The thermocouples were inserted parallel to the soil surface, taking into consideration all factors which could be thought to be of significance in the measurements (Pessi 1956, p. 31).

The depths at which the thermocouples were located were investigated upon conclusion of the temperature measurements (table 3). The differences in actual depth between the different test plots were so small that no corrections to the results of the temperature measurements due to depth were found necessary.

Soil temperature measurements were carried out at intervals of 4—7 days. The daily times of observation were 8 and 20 hours. The daily mean temperatures (t_m) were calculated from these observations according to the formula

$$t_m = \frac{1}{2} (t_8 + t_{20})$$

where t_8 and t_{20} are the observed temperatures of the said times of observation (cf. Pessi 1956, p. 37).

The minimum air temperature measurements were performed with the aid of alcohol minimum thermometers (R. Fuess). These thermometers were provided with a cylindrical radiation shield (Pessi 1954). The measurements were made at 5 cm height from the soil surface. Four replicates were used.

Table 3. Depth below soil surface of the thermocouples at the end of the investigation.

Depth, cm, 4. VI. 1955	Plot	Depth, cm, 18. IX. 1955			
		I	II	III	Mean
10	Not rolled	9.0	8.8	8.9	8.9
»	Rolled, cambr. roller	8.9	9.1	9.1	9.0
»	» , concr. roller	9.1	9.0	9.0	9.0
20	Not rolled	18.5	18.2	18.3	18.3
»	Rolled, cambr. roller	18.5	18.4	18.3	18.4
»	» , concr. roller	18.4	18.5	18.5	18.5

2. *Thermal conditions in the soil*

Fig. 1 shows the differences in temperature between the replicates at the different times of observation on the observation days. It is seen that at each depth the deviations have been of the same order of magnitude in all test plots, at their highest about 1.5°C. Since the actual depths of the replicates were not essentially different (table 4), the differences between the replicates are mainly due to inhomogeneities of the soil. The inhomogeneous character of this soil was due to undecayed residues of plants (mainly *Polytrichum commune*), which could still be noticed in the cultivated layer. In fig. 2 the variation of the temperature at 10 and at 20 cm depth on the different test plots during the growing season is shown. It is seen that at both depths the temperature was higher on the rolled plots than on the untreated plot up to the middle of July. The effect of rolling in increasing the temperature of the soil is also evident in Olsson's (1953) investigations. The greatest increase in the soil temperature has resulted from rolling with the concrete roller. This was probably caused by the fact that the frozen ground had thawed least, at least up to the beginning of June, at the points in which the thermocouples were placed on this test plot. This observation was made on 4. VI when the thermocouples were inserted. At corresponding depths the temperatures became approximately equal after the middle of July. Even in the first part of the summer the soil temperature differences at 10 and 20 cm depth cannot be considered very large. According to the investigations of Apsits (1934) and of Trygganov (1938), rolling increases the soil temperature by about 0.5°C.

The daily variation of the temperature was roughly similar in all test plots. On the rolled test plots the daily amplitude of the temperature was slightly higher, but after the plant cover had begun to shade the soil surface virtually no more differences between the different test plots were observable. Homén (1893) and Blohm (1927) have found that the temperature in

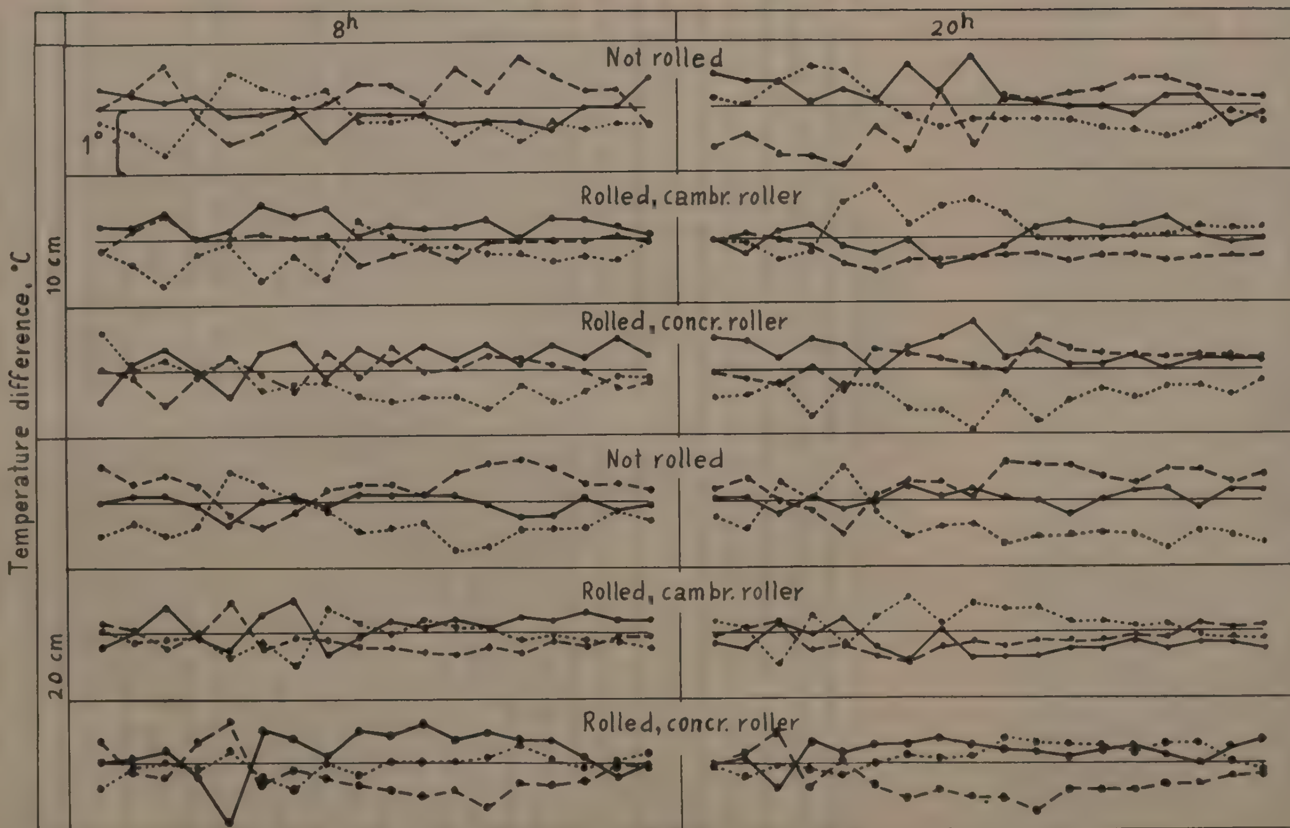

Fig. 1. Deviations of the replicates from their mean at various times of observation.

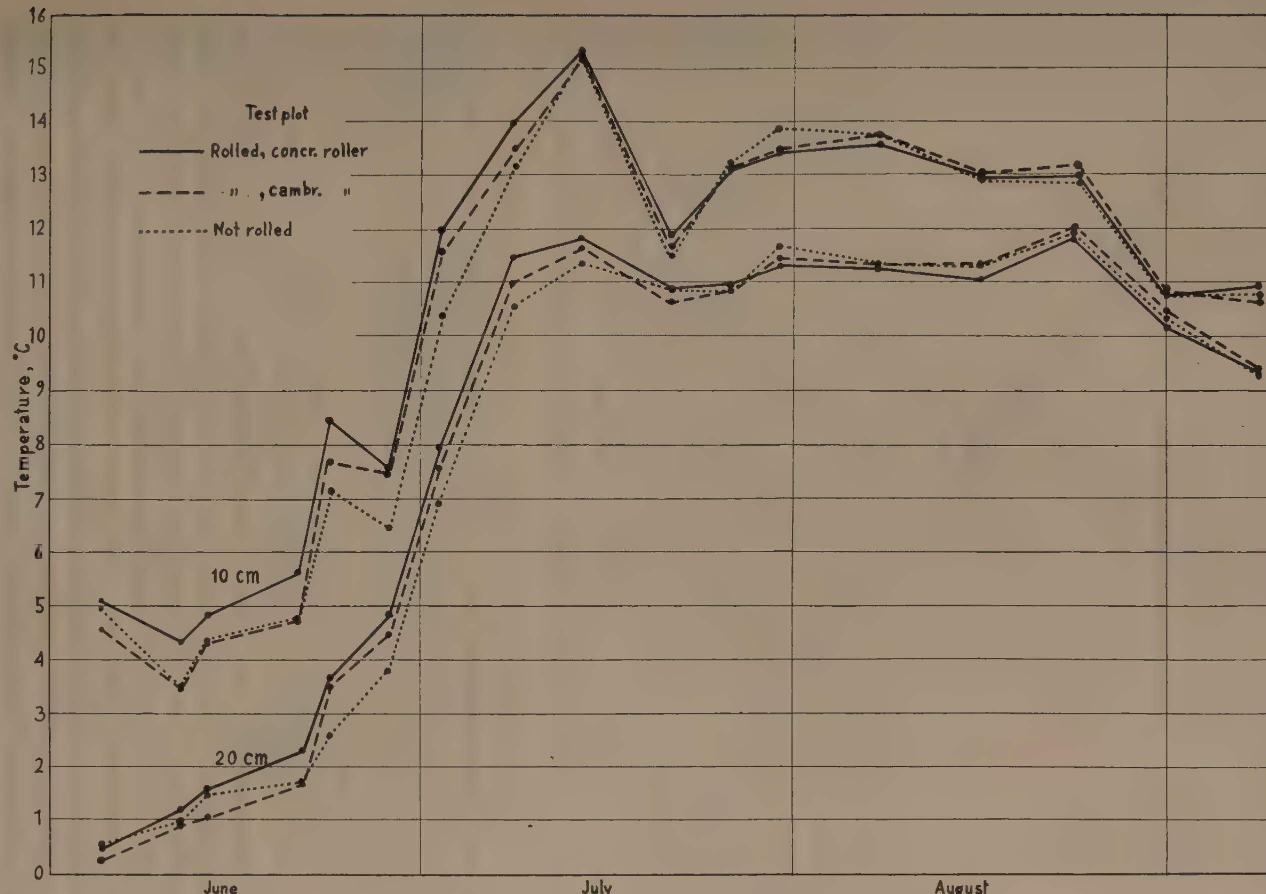

Fig. 2. Daily variation of temperature.

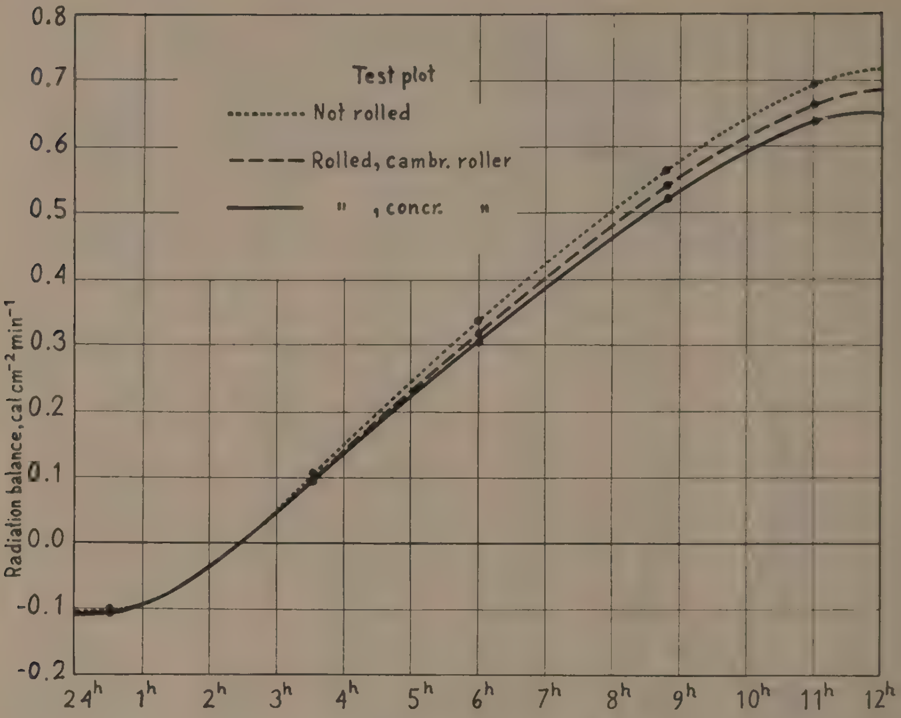

Fig. 3. Radiation balance on the different test plots on 22. VI. 1955.

compact soil is higher in the daytime and lower at night than in loose soil, with the exception of the soil surface. King (1910) has found the temperature in compact soil to be 1.7°C higher in the afternoon than in less compact soil.

3. *Temperature measurements of the air next to the ground*

Minimum air temperature measurements were made at 5 cm height from the soil surface during the first half of the growing season, when temperature differences could be excepted. During this time four frosty nights occured, the corresponding observations being presented in table 4. It is seen from the table that distinct differences in temperature occur between the different test plots. These differences are of the same order of magnitude as those observed by Olsson (1953). Howerer, they are not as great as those which can be brought about by the addition of mineral soil (Pessi 1956, p. 71).

Table 4. Minimum temperatures, °C, of four frosty nights at 5 cm height from the soil surface.

Night	Temperature, °C		
	Not rolled	Rolled, cambr. roller	Rolled, concr. roller
4— 5. VI. 1955	—4.2	—3.9	—3.2
7— 8. VI. »	—6.2	—5.5	—4.5
10—11. VI. »	—4.1	—3.5	—2.9
12—13. VI. »	—6.7	—5.5	—4.7
Mean	—5.3	—4.6	—3.8

4. *Thermal conductivity of the cultivated layer*

The thermal conductivity of a soil layer can be calculated when the specific heat of the soil and the times of occurrence of the daily temperature extremes, or the daily amplitudes, on either side of the soil layer are known. In the present case, however, the inhomogeneity of the soil surface, which was due mainly to the presence of undecayed plant residues, had the result that no reliable idea could be obtained of the variation of temperature at the soil surface. Accordingly, calculations relating to thermal conductivity based on these observations are bound to be comparatively inaccurate. A theoretical consideration, on the other hand, is likely to give a better idea of the changes in the thermal conductivity of the cultivated layer on the different test plots which are brought about by the procedure of rolling.

The changes in thermal conductivity caused by rolling are due to the compression of the soil. Admittedly this compression also affects the moisture conditions in the soil, but in the following these are assumed to be identical in all the test plots.

Since air is a poorer conductor of heat than soil, the improvement in thermal conductivity is an immediate consequence of the compression of the soil. According to previous investigations the thermal conductivity of the soil bears a closely linear relation to the volume of air in the soil (Smith 1938, p. 17—19). The thermal conductivity (k) of dry soil can be computed from the formula

$$k = k_2 P + k_1 (1 - P),$$

where k_2 = thermal conductivity of the air, P = porosity of the soil and k_1 = thermal conductivity of the soil material.

The total porosity of the soil was determined on 13. VI. The results of this determination are seen from table 5. It is noticed that the rolling has clearly compressed the cultivated layer. However, this compression was

primarily limited to its uppermost layer. Thus, no regular differences in total porosity could be found on the basis of four replicate determinations in the 10 to 20 cm layer. In these calculations the thermal conductivity of air was taken as 0.00005 and that of dry soil as 0.000123 cal/cm sec °C, this being the value found by SMITH and BYERS (1938, p. 17).

When the thermal conductivity of the dry soil is calculated for the 0 to 10 cm layer on the basis of these figures, the following values are obtained: Untreated plot 0.000107, plot rolled with cambridge roller 0.000121, and plot rolled with concrete roller 0.000129.

These values for the thermal conductivity may be used for a theoretical calculation of the temperature differences between the different test plots. employing the procedure used by PESSI (1956, p. 55) in his considerations relating to the effect of soil-improving agents. These calculations give as a result a maximum temperature difference in the first half of the summer of only about 0.4 °C (cf. fig. 2), i. e., the temperature of the cultivated layer on the rolled test plots should be warmer by this amount. However, owing to the differences in moisture conditions and evaporation, greater temperature differences have obtained in practice. In the above-mentioned theoretical consideration the assumption was made that evaporation has been of equal magnitude on all test plots.

5. *Radiation balance*

The difference between the radiant energy received by the earth's surface and the radiant energy lost is called the radiation balance of the earth's surface. In the daytime, when incoming radiation outweighs outgoing radiation, the radiation balance is positive. At night no short-wave radiant energy arrives on the earth's surface, and the radiation balance is negative. It would be of advantage from the standpoint of the warming up of the soil if it could absorb great amounts of radiant energy in the daytime and if its losses of energy in the night were low.

Since rolling smooths the soil surface and otherwise affects the physical properties of the soil, it also has an influence on the radiation balance. This question was studied, in connection with the rolling test, on 22. VI. Single series of measurements were further made on other days as well. However, no measurements of the radiation balance were made after the soil surface had become completely covered by vegetation.

The radiation balance was measured with the aid of a net radiation meter designed by SUOMI, FRANSSILA and ISLITZER (1954). The measurements were carried out by moving the instrument from plot to plot about five times and taking the mean of these values to represent the result for each plot.

Table 5. Total porosity and amount of water in the 0 to 10 cm layer on the different test plots on 13. VI. 1955. Four parallel determinations.

Plot	Total porosity, %	Water, per cent by volume	Water, per cent of air capacity
Not rolled	87.6 ± 3.2	43.5	49.5
Rolled, cambr. rolled	84.5 ± 2.9	41.5	49.0
» , concr. roller	82.9 ± 2.5	40.2	48.5

Fig. 3 shows the variation of the radiation balance during the first 12 hours of one day of observation. This series had to be interrupted on account of cloudiness in the afternoon. It is seen that in the night the radiation balance is of equal magnitude on all test plots, whereas the untreated plot absorbs more thermal radiation in the day than the rolled plots. The plot treated with the concrete roller shows the least absorption. This variation of the radiation balance is primarily due to the differences in the smoothness of the soil surface. The concrete roller leaves a fairly smooth surface, whereas the disks of the cambridge roller leave some residual irregularities, and the untreated test plot had a comparatively lumpy surface.

If it is assumed that with a clear sky the radiation balance would have been fairly similar in the afternoon to that recorded before noon, it is possible to calculate the excess of thermal radiation which the untreated plot receives during 24 hours in comparison with the plot treated with the concrete roller, for instance. This difference is found to be 3.57 cal/cm^2. If, furthermore, the specific heat of the soil is assumed to be 0.8 cal/cm^3 °C, this additional energy is found to be capable of raising the temperature of a soil layer of 20 cm thickness by 0.24 °C per day.

Although rolling improves the thermal conductivity of the soil, thus promoting the warming-up of the soil in the early part of the summer, the tendency for temperature differences to exist between rolled and untreated soil is counteracted by the greater ability of the latter to absorb thermal radiation during the day. The theoretically best treatment of the soil would be to render the soil surface fairly uneven in connection with, or after, the rolling operation.

Summary

A field rolling test was arranged at the frost research station at Pelsonsuo during the summer of 1955, with oats and barley as experimental plants. The test area was a peat bog which had been cleared for cultivation two years before and which had a very loose cultivated layer, its peat consisting of sedge peat. The test comprised plots treated with a cambridge roller and a concrete roller, respectively, and an untreated plot, there being seven replicates of each treatment. Measurements of the soil and air temperatures were carried out in connection with this test.

Rolling increased the grain and straw yields of oats and barley (table 2). In the case of barley the increase in grain yield was 160 and 184 % respectively, as compared with the untreated test plot; with oats only 29 and 32 %. The corresponding figures for the straw yield were 76 and 74, and 36 and 38 %, respectively. However, the crops were unusual throughout in that the ratio between straw and grain yield exceeded 3 : 1 on all test plots. The straw yield achieved normal values, whereas the seed yields were lower than normal.

Rolling increased the temperature of the cultivated layer in the early part of the summer, the highest temperature differences being 1.5° C (fig. 2). Similarly, the minimum air temperatures on the frosty nights of the early summer were higher on the treated test plots (table 4).

It is not possible to carry out an accurate analysis of the factors contributing to the said increase of the crop yield, but the following conclusions can be presented:

1. The differences between the different test plots with regard to the thermal conditions in the soil and in the air next to the ground were not of sufficient magnitude to account for the differences in crop yield.

2. The difference in the moisture conditions of the test plots cannot alone be the cause of the observed differences in crop yield, for the following reasons: No symptoms indicative of drought were observed in the plants. The magnitude of the straw yield is also proof of the prosperity of the vegetation in every case. If the differences were due exclusively to different moisture conditions, the ratio between the straw and grain yield could not

have reached such high values ($> 3:1$). Changes in the grain crops due to drought would not be manifested by the formation of light grain, such as appeared in this case.

3. The main reason for the increased crop yield achieved with the aid of rolling is thought to be the fact that the roots of the plants gain closer contact with their nutrient layer when this layer has been compressed with the aid of the roller; in all likelihood this is of significance in numerous respects with regard to the nutrition of the plants. Without rolling the cultivated layer was very loose. One of the possible causes is that rolling improved the supply of copper, defiency of which was amply observable and probably also constituted the reason for the formation of light grain. This suggestion is further borne out by the fact that on the same bog also compressing of the soil brought about by the addition of mineral soil has improved the supply of copper.

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Selostus

Jyräyksen vaikutuksesta ohran ja kauran satoon sekä suoviljelyksen länpöoloihin

Yrjö Pessi

Hallakoeasema, Pelsonsuo

Hallakoeasemalla Pelsonsuolla järjestettiin kesällä 1955 jyräyskoe, jossa koekasveina olivat ohra ja kaura. Koealue sijaitsi kaksi vuotta aikaisemmin viljelykseen raivatulla suolla, jonka muokkauskerros oli löyhää. Turve oli saraturvetta. Koejäsenenä olivat jyräämätön sekä kamrikkijyrällä ja betonijyrällä jyrätty ruutu. Kertauksia oli seitsemän. Kokeen yhteydessä suoritettiin maan ja ilman lämpötilan mittauksia.

Jyräys kohotti ohran ja kauran jyvä- ja olkisatoja. Ohralla jyväsatojen lisäykset olivat 160 ja 184 % jyräämättömään koejäseneen verrattuna, mutta kauralla vain 29 ja 32 %. Olkisatojen vastaavat luvut olivat 76 ja 74 sekä 36 ja 38 %. Sadot muodostuivat kuitenkin kauttaaltaan epätavallisiksi siinä suhteessa, että olkisadon suhde jyväsatoon oli suurempi kuin 3 : 1 kaikilla koejäsenillä. Olkisadot muodostuivat normaaleiksi, mutta jyväsadot jäivät normaalia pienemmiksi.

Jyräys kohotti alkukesästä muokkauskerroksen lämpötilaa suurimpien lämpötilaerojen ollessa 1.5 °C. Ilman minimilämpötilat olivat alkukesän hallaöinä myös korkeampia jyrätyillä ruuduilla.

Niiden tekijöiden erittelyä, joiden vaikutuksesta sadot lisääntyivät mainitulla tavalla, ei tarkasti voida suorittaa. Seuraavia päätelmiä voidaan kuitenkin esittää:

1. Muokkauskerroksen ja maan pinnan läheisen ilmakerroksen lämpöolot poikkesivat eri koeruutujen kesken siksi vähän, etteivät lämpöolojen eroavaisuudet voi aiheuttaa kokeessa esiintyneitä satoeroja.

2. Maan kosteusolojen erilaisuus eri koeruutujen kesken ei ole voinut yksinomaan aiheuttaa kokeissa esiintyneitä satoeroja seuraavista syistä: Kuivuuden aiheuttamia symptomeja ei havaittu kasveissa. Olkisatojen suuruus osoittaa myös kasvustojen rehevyyttä. Mikäli yksinomaan kosteusolojen erilaisuus olisi aiheuttanut erot, ei olkisatojen suhde jyväsatoihin olisi muodostunut näin suureksi ($> 3 : 1$). Kuivuuden jyväsadoissa aiheuttamat muutokset eivät ilmensisi kahujyvien muodostumisena, mitä nyt esiintyi.

3. Pääsyynä jyräyksen aiheuttamiin sadon lisäyksiin lienee se, että jyrällä tiivistetyssä kasvualustassa kasvin juuret saavat tiiviimmän kosketuksen kasvualustaan, millä on todennäköisesti monessakin suhteessa merkitystä kasvien ravitsemukselle. Jyräämättömän koejäsenen muokkauskerros oli erittäin löyhää. Eräänä syynä saattaa olla kuparilannoituksen erilainen vaikutus eri koeruuduilla, sillä kuparin puutos oli ainoa epänormaalin kehityksen symptomi. Tätä otaksumaa tukee lisäksi se havainto, että samalla suolla kivennäismaan aiheuttama maan tiivistyminen on parantanut myös kasvien kuparin saantia.